An Object-Oriented, Knowledge-Based System for Cardiovascular Rehabilitation - Phase II

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The Heart Monitor is an object-oriented, knowledge-based system designed to support the clinical activities of cardiovascular (CV) rehabilitation. The original concept was developed as part of graduate research completed in 1992. This paper describes the second generation system which is being implemented in collaboration with a local heart rehabilitation program. The PC UNIX-based system supports an extensive patient database organized by clinical areas. In addition, a knowledge base is employed to monitor patient status. Rule-based automated reasoning is employed to assess risk factors contraindicative to exercise therapy and to monitor administrative and statutory requirements.

INTRODUCTION

Heart rehabilitation is an interdisciplinary medical care program which provides therapy for patients with coronary artery disease (CAD). The program is not limited to patients with CAD, but may include patients who wish to improve or maintain cardiovascular fitness for a variety of reasons. The goal of rehabilitation is to prescribe and implement an individualized plan of exercise therapy and lifestyle modification which retards the atherosclerotic process while optimizing patient physiological, psychosocial, and vocational well-being.

The Heart Monitor is an object-oriented, knowledge-based system conceived during graduate research [1] and described in 1991 [2]. The research goal was to determine if a system employing contemporary technologies could fulfill the daily requirements of heart rehabilitation while supporting long-term research. There is no known comprehensive system which applies these technologies to CV rehabilitation.

A project was undertaken in 1993 to implement the system in a low-cost hardware/software configuration. The 386 processor, UNIX operating system and an object-oriented database development tool, provided the environment for this pursuit.

THE PATIENT

The candidate for entry into a heart rehabilitation program has recently experienced a cardiac event, typically an acute myocardial infarction (AMI) or coronary artery bypass graft (CABG) surgery. A patient must be referred to a rehabilitation program by a physician and sign an informed consent form which enumerates the program's goals, outlines the obligations of each party and states that exercise therapy carries the risk of additional cardiac events.

Cardiovascular rehabilitation focuses on the individual needs of the patient. Through personal interviews, screenings, diagnostic tests and verbal tests, patient status is assessed and a program of exercise and life style modification is prescribed.

The patient attends three supervised therapy sessions per week, engaging in programmed exercise and education. During the early phases of exercise therapy, the heart (using ECG) and blood pressure are closely monitored. The patient is assessed in terms of clinical observations and progress. If the patient progresses satisfactorily, the prescription is modified to increase the exercise intensity level.

THE REHABILITATION CLINIC

The daily activities of the rehabiltation clinic focus on a patient individualized program of exercise to increase cardiac function and education to modify lifestyle factors causal to CAD. The program consists of four phases. A patient may enter the program in any phase, based on assessment and the physician's referral.

Phase I - In-hospital period of 6 to 14 days for patient recovering from AMI or CABG surgery. Patient begins supervised exercise at levels less than 5 METs.

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The Medical Database

The system supports a medical database organized by typical hospital functions. ***The Heart Monitor*** emphasizes the CV aspects of rehabilitation, but the system can be modified to focus on other clinical areas.

Figure 1 shows the menu hierarchy for the medical history segment of the database.

MEDICAL HISTORY
- CURRENT DATA
  - Current Symptoms
  - Physicians
  - Hospital Admissions
- FAMILY HISTORY
- CARDIOVASCULAR
  - Myocardial Infarctions
  - CV surgery
  - Angina Warning System
  - CV Diseases
- RESPIRATORY
- NEUROLOGICAL
- GASTRO/URINARY
- ORTHOPEDIC
- EYE, EAR, NOSE, THROAT
- SURGERY
- ALLERGIES
- IMMUNIZATIONS/INFECTIONS
- DENTAL
- OTHER HISTORY

Figure 1. Medical History Hierarchy.

The Knowledge Base

The unique feature of the system is its knowledge base which contains about 70 *if-then* rules primarily for assessing the patient risk of a cardiac event during exercise therapy. As noted earlier, the patient is categorized on the basis of this risk as EXCLUDED, HIGH risk, INTERMEDIATE risk or LOW risk.

The knowledge base (KB) may be invoked on demand for all patients or a specific patient. The user may choose to display/print a listing of all rules and their result, or only those rules which place the patient in anything other than a LOW risk. Optionally, the KB may be conveniently scheduled to automatically review all active patient records.

Using multitasking, the KB can be invoked in a background mode, leaving the system free to accomplish other tasks. In fact, the KB is automatically invoked each time a patient record is selected making the current risk available to the user. All contraindications to exercise therapy discovered by the system during risk assessment are sent to a clinical bulletin board where the staff may display or print the date/time stamped results.

The Exercise Prescription

The exercise prescription is established on-line. To facilitate an accurate prescription, several aspects of the database are readily available as the prescription is formulated:

Functional capacity - Using Graded Exercise Testing (GXT) results or patient responses to questions, functional capacity in METs can be determined and employed in determining exercise intensity levels.

Medications - Current medications may effect target heart range.

CV Medical History - Myocardial infarctions, CV diseases and surgery, and angina warning system data are available.

Target Heart Rate Range - Using resting and maximum (age computed or symptom limited) heart rates, the exercise intensity range is specified and the system computes target heart rate range.

Activity Master File - Standard activities may be selected from a pop-up list and the required parameters for that activity are displayed. For example, if treadmill is selected, the parameters SPEED, MINUTES and GRADE are displayed.

MET Calculations - After activity parameters are entered, METs are calculated to confirm the prescribed intensity level of exercise [4].

Note: Metabolic equivalents (METs) are a measure of the amount of oxygen the body consumes (metabolic rate) and is directly proportional to the level of exertion. At rest, the metabolic rate is 1.0 MET.

Phase II - Convalescent period of 8 to 12 weeks centering on closely monitored outpatient exercise therapy and lifestyle modification. Patient goal is to achieve greater than 5 METs during this phase.

Phase III - Maintenance period of supervised outpatient activities with a goal of achieving greater than 8 METs in 4 to 6 months.

Phase IV - Unsupervised period of indefinite length in which the patient maintains cardiovascular fitness through regular, moderate exercise.

Minimal record keeping requirements of heart rehabilitation include:

1) a physician referral.

2) a consent form signed by the patient.

3) patient medical history, especially aspects relevant to cardiovascular rehabilitation. Of special interest are current symptoms and diagnostic test results which are required for risk analysis.

4) the exercise prescription which is patient individualized and based on the patient's functional capacity (in METs), current symptoms and medications, and other factors, such as pacemaker implants, which effect heart rate.

5) results of exercise therapy, including activity level achieved (METs) and measurements of heart rate and blood pressure at various levels of exertion. Also included is patient reported symptoms and staff observations and progress notes.

Additional information which is useful in setting goals and evaluating patient status includes an inventory of lifestyle factors such as nutrition, activity level, psychosocial evaluation, smoking, drinking, knowledge of the fundamentals of heart disease, patient medications and safety aspects of exercise therapy.

RISK

There are two types of CV risk. The risk of morbidity and mortality due to CAD may be reduced by addressing lifestyle factors in the following areas: stress, hypertension, diet, obesity, smoking and sedentary versus active lifestyle.

A second type of risk occurs when participating in exercise therapy. Due to medical conditions, the patient may be unable to exercise or may be at risk of experiencing a cardiac event during exercise. Some conditions require that the patient be excluded from therapy; other conditions place the patient at high, intermediate or low risk and require modification of the exercise prescription [3].

SYSTEM DESIGN

The ideal system to support cardiovascular rehabilitation contains or has direct access to the patient's medical database and is capable of clinical data exchange with heterogeneous systems. The system incorporates a knowledge base to provide decision support in rehabilitation planning and monitoring patient status during therapy.

The Object-Oriented Paradigm

The characteristics and advantages of object-oriented programming (OOP) are thoroughly discussed by Meyer [5]. A main advantage is the intuitive nature of OOP systems. Each element in the clinical system is an object - patient, doctor, department, exercise. The OOP paradigm reduces the cost of implementation and maintenance [6]. The availability of OOP database development tools facilitates use of this technology.

The Heart Monitor employs Dataflex, an OOP database development tool selected because it

1) meets all system requirements.

2) is low cost.

3) works in a PC Unix environment.

4) creates software portable to other platforms.

5) is well-supported.

System Inputs

The system supports three methods of data input:

Manual: This method is intended for direct data entry when interviewing patients. The system guides the interviewer through the data essential for registration, initial assessment and periodic updates. Pop-up lists eliminate the need for keying medical terms and other demographic data.

The system also guides the interviewer through data that is essential for risk analysis. If risk data is not available, the system will inform the user.

Scannable Forms: The primary purpose of the scanner is to capture exercise data. The system preprints a scannable exercise data sheet with patient identification including barcode, current medications, scheduled exercises. The patient reports changes in medications, smoking status and current weight, then enters heart rate and blood pressure at rest, during warmup, during exercise and after cooldown. The patient may also enter any symptoms experienced during the session. The staff enters observations and progress codes.

The scanner can also be used to capture lifestyle data.

Clinical Data Interchange (CDI): Although the current system does not support it, CDI can be accomodated and implementation is scheduled for early 1996 using the standard Health Level Seven (HL7) [7].

System Outputs

The system provides reports typical to heart rehablitation. The Exercise Summary Reports are especially useful in that they demonstrate the efficacy of rehabilitation by reporting trends in weight loss, exercise intensity level (METs), blood pressure, calories expended, equivalent miles, symptoms and progress.

Database queries may be created to identify patient sub-groups, for example, how many patients in a certain age, ethnic and gender group have had CABG surgery within the past year. Each clinical area of the medical history may be individually displayed or printed.

DISCUSSION

The system described is currently undergoing tests in a clinical environment. It has been demonstrated that a contemporary, low-cost system meeting the daily requirements of a heart rehabilitation clinic is feasible.

During the next several months, remote system maintenance and clinical data exchange using HL7 will be implemented. In addition, the use of ICD-9 and SNOMED codes will be investigated.

The pooling of data for research purposes will also be implemented.

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